B

Navy Department - Office of Research and Inventions

NAVAL RESEARCH LABORATORY
Washington, D.C.

FR-2869

* * *

SHIP-SHORE RADIO DIVISION - M. and C. SECTION

27 June 1946

INVESTIGATION OF RMA AND NRL TRANSFORMER TEST CHAMBERS FOR PROPOSED SPECIFICATION JAN-T-27

By G. L. Anderson and H. S. Robertson

- Report R-2869 -

* * *

Approved by:

S. G. Lutz, Head, M. and C. Section

L. A. Gebhard, Superintendent,
Ship-Shore Radio Division

Commodore H. A. Schade, USN
Director, Naval Research Labor

Preliminary Pages ....a-c
Numbered Pages........1-6
Plates................12
Distribution List..... d

ABSTRACT

The RMA standard transformer test chamber has serious defects which restrict its usefulness for temperature rise and overload measurements required by the transformer specification PRO-JAN-T-27. A proposed substitute chamber designed and constructed at this Laboratory is superior in the following respects: (a) the temperature distribution is more uniform; (b) the size is much smaller; (c) the weight is less; (d) the heater power consumption is less; (e) the chambers can be stacked.

TABLE OF CONTENTS

INTRODUCTION

1. The writers of PRO-JAN-T-27 Specification for transformers and inductors, (reference (a)), have emphasized the need for standardizing test methods and procedures. This is in recognition of the fact that the test results of various laboratories would be meaningless without such standardization. For the temperature rise measurements of JAN-T-27, the authors have specified a standard still-air chamber to be used by all testing agencies. The specified chamber is the one now in use by the Radio Manufacturer's Association for transformer tests at 40°C. (Reference (b)) In the course of a study of PRO-JAN-T-27 conducted by this Laboratory at the request of Code 930B of the Bureau of Ships, it was found that the RMA chamber contained objectionable temperature gradients and was very inefficient. The purpose of this report is to present the results of an investigation into the suitability of the RMA chamber, and to describe a proposed substitute chamber developed by this Laboratory to evade the limitations found in the RMA chamber.

DESCRIPTION OF RMA CHAMBER

2. As described in reference (b) the RMA chamber is a 2-foot cube whose sides are composed of 1-inch thick white asbestos sheeting. The only ventilation possible is through a six-inch square opening located centrally at the botton of one side and protected from external drafts. During the test the transformer is located in the center and three inches above the base of the enclosure and supported by two wooden cleats. The thermometer for measuring the temperature of the air within the test-enclosure is mounted horizontally extending through a small hole in the chamber wall and located so that the bulb is three inches from the base and three inches from the nearest rear and side walls. The bulb of the thermometer for measuring the temperature of the core is maintained in contact with the core by means of glazier's putty. The temperature of the windings is determined by the resistance method. The ambient temperature of the enclosure is to be maintained at 40°C throughout the test. The temperature rise for a given load condition is determined then by subtracting the ambient temperature of the air within the enclosure from the temperature of either the core or the windings, whichever is higher.

3. In constructing the above chamber the "white asbestos sheeting" was interpreted to mean "transite", a commercial sheeting made of asbestos fibers and portland cement. To obtain the 40°C ambient temperature, four 350-watt vitreous enameled strip heaters were used, mounted on stand-off-insulators one inch below the top of the chamber.

TEST OF THE RMA CHAMBER

4. In the evaluation of the RMA chamber, test procedures were designed to ; (1) check temperature distributions within the chamber and compare with stated ambient temperature, (2) determine the power consumption required to maintain a given temperature, (3) investigate the

effect of room temperature on the temperature within the enclosure, and (4) to investigate the possibility of stacking the chambers so as to conserve floor space when more than one chamber is necessary.

5. Temperatures within the enclosure were measured by means of Weston dial thermometers, thermocouples, and mercury thermometers. The curves, Plate 1, are based on measurements made with dial thermometers, placed so that the temperature was measured twelve inches from the side of the chamber in which the six-inch square hole is cut, six inches from the front of the chamber, and at the heights indicated by the points on the curves. The other temperature measuring devices were used to ascertain that the dial thermometer measurements were representative of the general temperature distribution. Heater power consumption was checked by voltage and current measurements. The effect of room temperature was checked merely by noting variations in the temperature within the enclosure as room temperature changed. To investigate stacking of the chambers, a mercury bulb thermometer was placed on the outside top surface of the chamber and shielded from air currents.

6. To provide a "load" in the chamber a simulated transformer, consisting of an incandescent bulb inside a 16-gage steel box 4" x $4\frac{1}{2}$" x $5\frac{1}{4}$" high, was mounted as specified in reference (b).

EVALUATION OF THE RMA CHAMBER

7. The termperatures at various heights in the chamber were plotted into curves shown on Plate 1. It was found that a very great temperature difference existed between the top and the bottom of the chamber. The average difference, for several ambient temperatures at the 3-inch level, was 57.7°C. With a 40°C temperature at 3 inches above the base, the top of the chamber at 22 inches was 90°C and the outside top surface was 99°C. Assuming the transformer under test to have a height of six inches, the ambient air temperature at the top of the transformer would be approximately 7°C above that at its bottom. No measurements were made with the "transformer" under load.

8. Heater power consumption was found to be very high, with a total of 1400 watts required to bring the ambient temperature at the 3-inch level to 65°C.

9. Variations in room temperature caused large variations in the ambient temperature and consequently varied the heater power necessary. Variations in room temperature therefore changed the temperature gradients in the chamber by requiring more or less heater input. No quantitative measurements of gradient as a function of room temperature were made. Measurements were made, however, of gradient with the opening closed, half closed, and open. The resultant curves, Plate 1, show a definite decrease in gradient when the opening is closed.

10. In summary, it is concluded that the RMA chamber contains temperature gradients of such great severity as to make the value of temperature rise measurements doubtful. The excessive heater power required, together with the effect of room temperature variations on

chamber temperature leads to the conclusion that the temperature control system is poor. The very high temperature on the top outside surface of the chamber prohibits the stacking of chambers to conserve floor space.

DESIGN CONSIDERATIONS FOR A SUBSTITUTE CHAMBER

11. The results of the above tests together with the conclusions drawn led to the conviction that a chamber could be built which would surmount many of the weaknesses found. The high heater power required and steep temperature gradients indicated a chamber of smaller size and with a better temperature control system. A chamber was designed and constructed which consists of a double box made of 16-gage galvanized sheet steel. (See Plate 2 to 4) The inner box is a 15-inch cube supported by non-metallic supports of low thermal conductivity within the outer box, a 20-inch cube, and positioned to provide a $2\frac{1}{2}$-inch air space on each side. The door consists of a single sheet of 16-gage galvanized steel with its center portion constructed to provide a $2\frac{1}{2}$-inch dead-air space at the front of the chamber and a recess for the observation window. The door fits tightly enough to prevent ventilation. A 9-inch by 7-inch pyrex oven window is mounted in the center of the door. The opening in the face of the door is smaller than the pyrex window so that the window is mounted in the recess and held in the position against the front of the door by retaining angles attached to the sides of the recess.

12. A single 250-watt strip heater is mounted on each of the side walls parallel to and three inches above the bottom, and a 350-watt heater is mounted similarly on the rear wall. On the door a 250-watt strip heater is mounted two inches from the bottom of the chamber. The heaters are connected in a series-parallel arrangement as shown on Plate 2.

13. Connections are made to the heaters, load, and thermostat by the use of terminal strips mounted on the inner and outer walls of the chamber. These terminals are located in the upper left hand corner near the rear of the box and are connected together by #8 wire inserted in varnished cambric tubing.

TEST OF THE PROPOSED SUBSTITUTE CHAMBER

14. In order to evaluate the substitute chamber tests were made to check its temperature gradients, power consumption, and outside surface temperature. A simulated transformer was mounted centrally in the chamber, three inches above the bottom. This transformer, the same as that used in tests of the RMA chamber, consisted of a 16-gage steel box 4" x $4\frac{1}{2}$" x $5\frac{1}{4}$" high which inclosed an incandescent bulb. Power up to 50 watts could be dissipated in this "dummy load".

15. To check temperature gradients, a network of thermocouples was installed as shown on Plate 5. There were 21 thermocouples in each of three layers and 20 in a fourth layer. The layout was based on the assumption that a symetrical temperature distribution could be expected with respect to a vertical plane of centers perpendicular to the door of the chamber.

16. Temperatures were measured by means of a pyrometer-potentiometer. Temperature cycling in the chamber was checked with a recording resistance thermometer. The results of the cycling measurements were not recorded because cycling is a characteristic, not of the chamber, but of the thermostat-heater-chamber thermal system. It was necessary to use large mercury thermostats for ambient temperature control during most of the measurements. These thermostats possess a large thermal capacity and as a result failed to follow changes as rapidly as was desirable. Even with this unfortunate situation, cycling in the neighborhood of the thermostat did not exceed a 2°C peak-to-peak excursion. These cycles caused an apparent temperature gradient because of the time required to complete a set of readings.

17. Temperature distributions were measured with the control thermostat set at 40°C, 60°C, 66°C, 85°C, and 98°C at "transformer" load dissipations of 0, 10, 25, and 50 watts. Results of measurements at 40°C, 66°C, and 98°C with load dissipations of 0 and 50 watts are shown on Plates 6 to 12.

18. To check the outside surface temperatures, mercury bulb thermometers were placed against the top and bottom outside surfaces and shielded from air currents. Heater power consumption again was checked by current and voltage measurements. The effect of room temperature variations on chamber temperature was noted but not recorded.

EVALUATION OF THE PROPOSED CHAMBER

19. As shown by the data of Plates 6 to 12, temperature distribution in the proposed chamber was quite uniform. With no load to the "transformer". gradients did not exceed 2°C for any degree of controlled chamber temperature. With 50 watts applied to the "dummy load", the gradient from the $1\frac{1}{2}$" to the 12-3/8" levels did not in any case exceed 11°C. Assuming a transformer of six inches height, the ambient air temperature difference from bottom to top of the transformer would vary from 2°C for no input to the "load" to 7°C for 50 watts input to the "load".

20. Room temperature variations were found to have some effect on chamber temperature, but not enough to disturb chamber gradients. At normal room temperature and a controlled chamber temperature of 40°C, the maximum transformer "load" that could be handled without external cooling was 25 watts. For controlled chamber temperatures of 60°C and above, "loads" up to 50 watts could be handled with ease. To maintain a chamber temperature of 98°C, the maximum heater power required was 700 watts. At a chamber temperature of 98°C, the top outside surface of the chamber did not exceed 55°C. Also, the temperatures of the top and bottom outside surfaces differed by less than 10°C.

COMPARISON OF THE RMA AND PROPOSED CHAMBERS

21. Temperature gradients of the proposed chamber are considerably less severe than those of the RMA chamber. Under no-load conditions, the top-to-bottom gradient of the proposed chamber was a maximum of 2°C compared to an average of 57.7°C for the RMA chamber. With 50 watts

input to the load, the top-to-bottom difference of the proposed chamber temperature was a maximum of 11°C, considerably less than the 57.7°C of the RMA chamber with no load input.

22. The 700 watts heater power needed to keep the proposed chamber at 98°C represents a great improvement over the 1400 watts needed by the RMA chamber to attain a temperature of 65°C.

23. While the temperature of the top outside surface of the RMA chamber actually exceeded the enclosure temperature, the top of the proposed chamber did not exceed 55°C for an enclosure temperature of 98°C. While stacking of the chamber is prohibitive in the first case, it can be permitted in the second, thus affording considerable conservation of floor space.

24. While room temperature variations had a great effect on the temperature gradients and power consumption of the RMA chamber, the proposed chamber was effected to such a small extent that the effect could be overlooked.

25. Against the more than 200-pound weight of the transite RMA chamber, the proposed chamber weighs approximately 86 pounds and can, if necessary, be lifted and moved about by one man.

26. The RMA chamber, a 2-foot cube, occupies in excess of 8 cubic feet of space, while the 20-inch cube proposed chamber occupies approximately 4.6 cubic feet. Two of the 20-inch chambers, stacked, would use approximately 4 square feet of floor space, while two 2-foot transite chambers would require approximately 10 square feet.

CONCLUSIONS

27. It is concluded that the proposed transformer test chamber represents an improvement over the chamber presently specified in PRO-JAN-T-27 in the following respects:

(a) Temperature distributions are more uniform and the gradients are less severe.

(b) The physical size is much smaller.

(c) The weight is less than half.

(d) The power consumption is less than half.

(e) The chambers can be stacked.

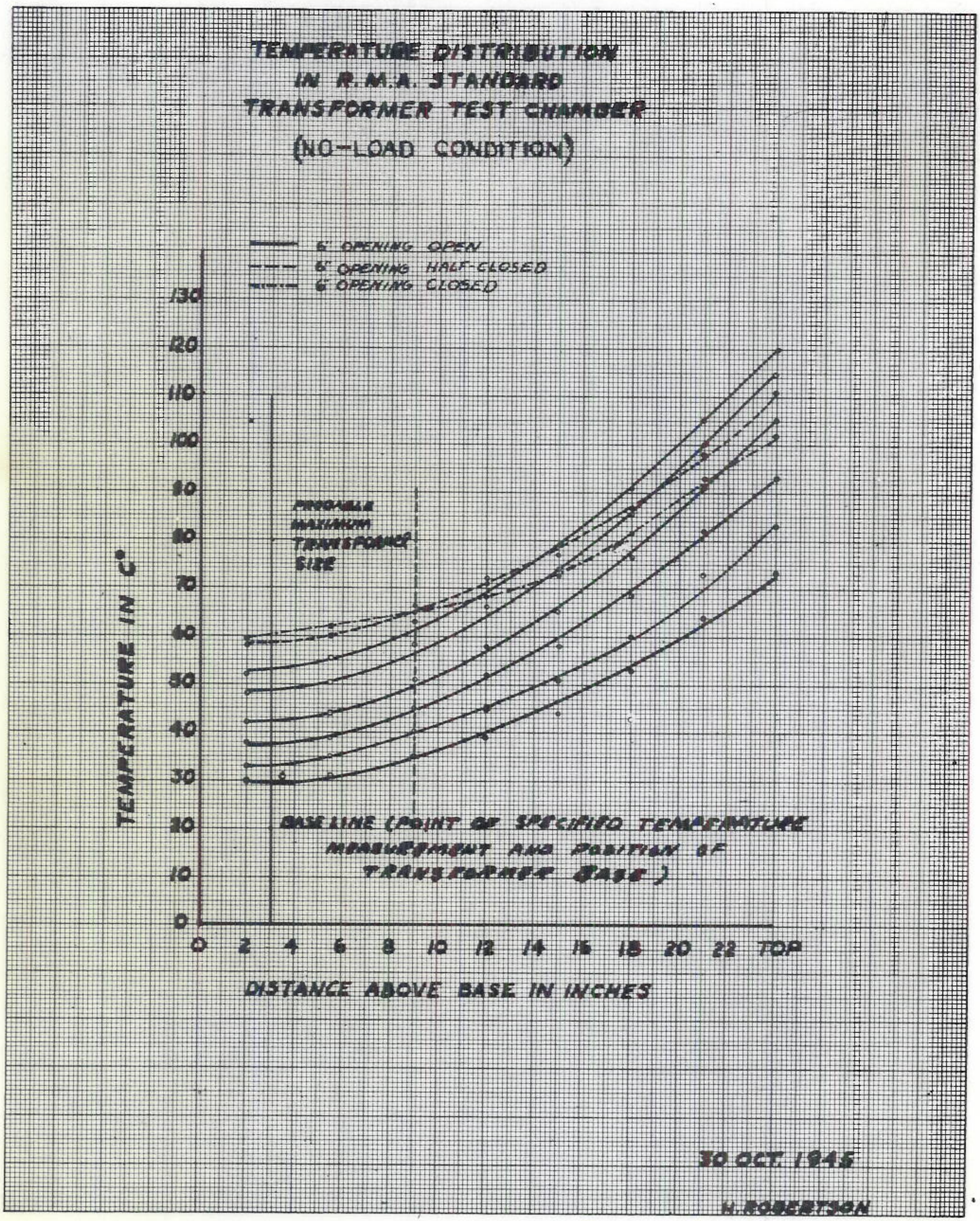
RECOMMENDATIONS

28. Since a standard transformer test chamber should be specified in JAN-T-27, and since the proposed substitute chamber has been found to be far superior to the RMA chamber presently specified, it is recommended that a chamber of the type described herein be adopted as the standard still-air chamber for the tests required in JAN-T-27.

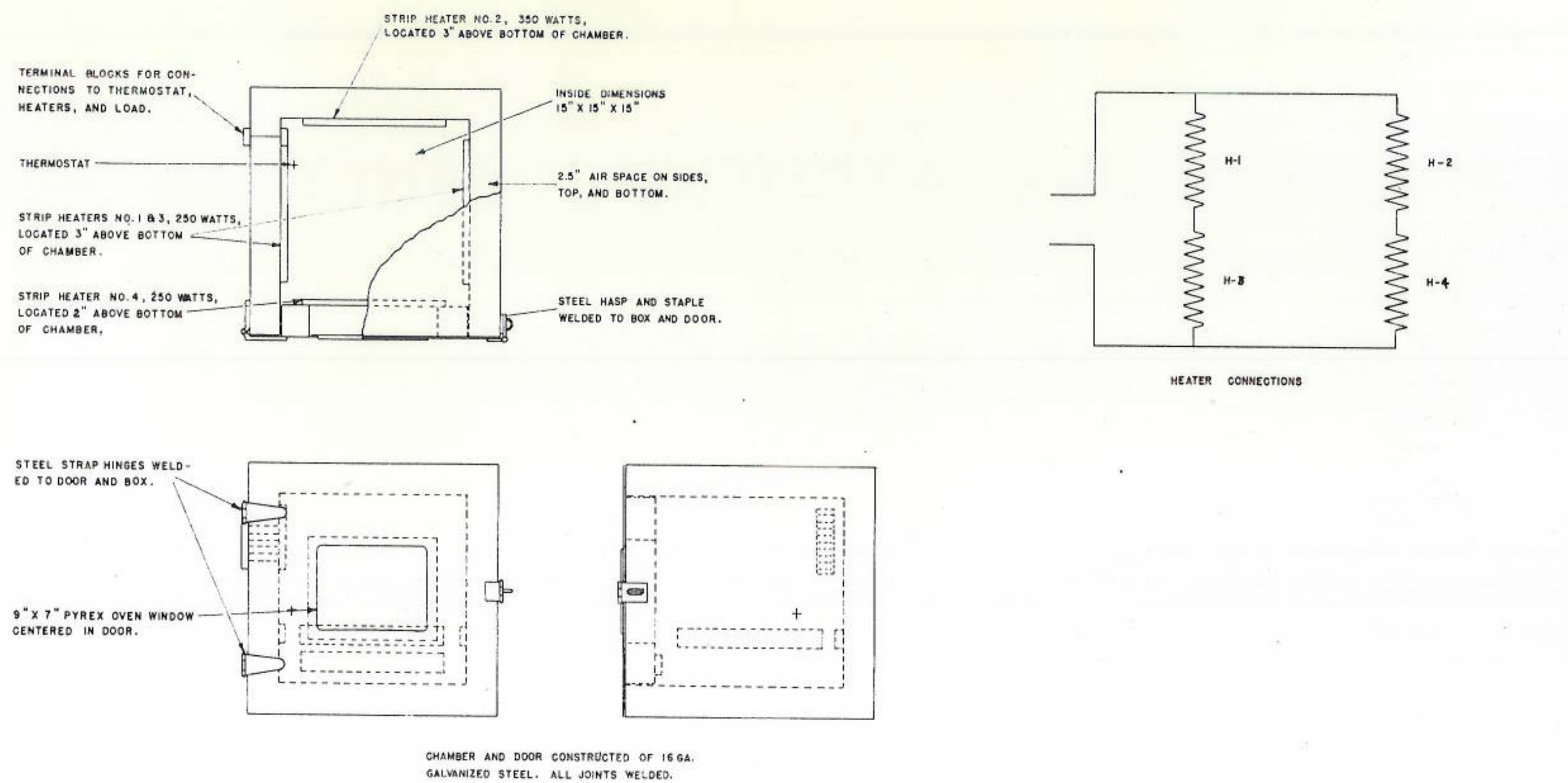
REFERENCES

1. Proposed Joint Army-Navy Specification JAN-T-27 Transformers and Inductors (Audio and Power), Bureau of Ships Specification 16T30 (INT) dated 15 August 1945.

2. Radio Manufacturer's Standards; Sheet 416; Component Parts Section; Subject - Radio Power Transformers; Paragraph M4-546; Date of Issue - 5 January 1938.

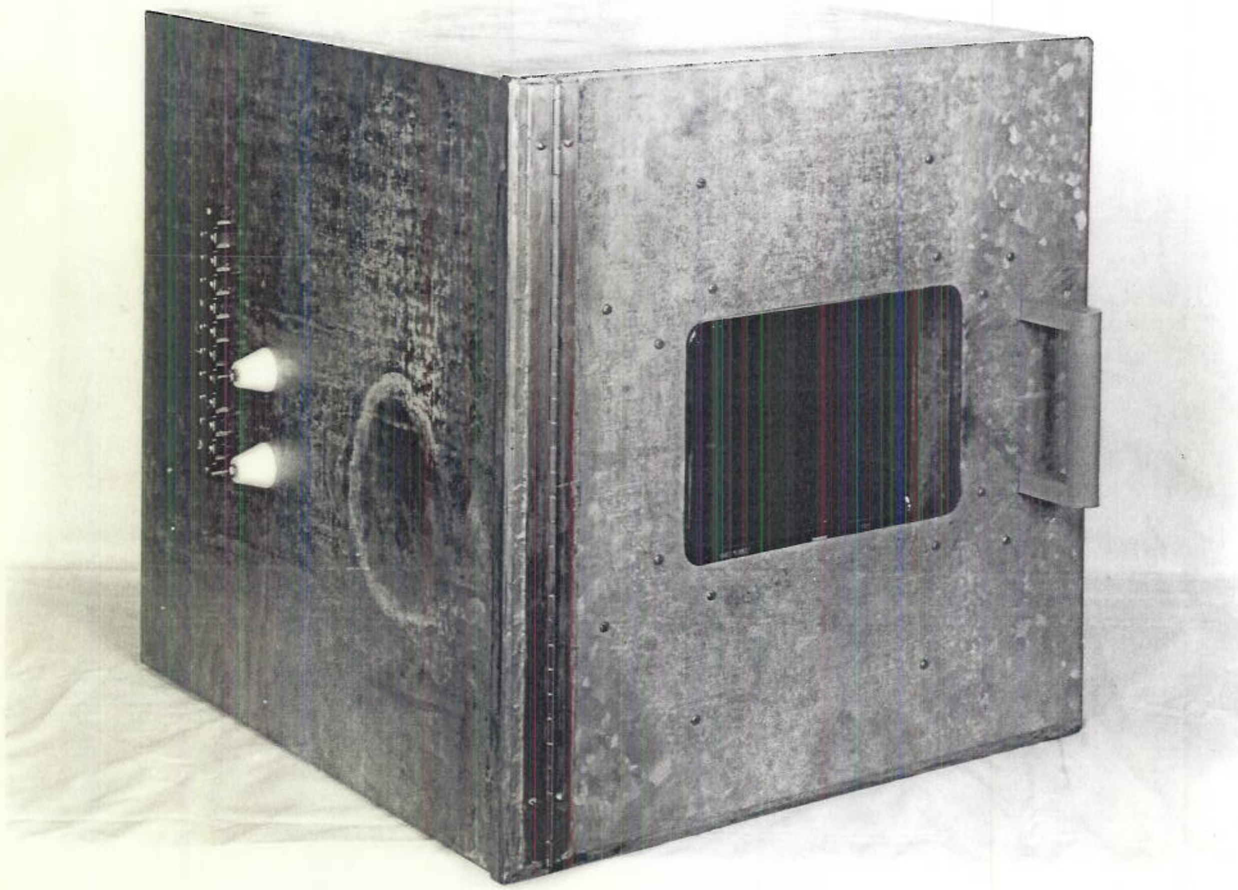


TEMPERATURE DISTRIBUTION
IN R.M.A. STANDARD
TRANSFORMER TEST CHAMBER
(NO-LOAD CONDITION)
6" OPENING OPEN
6" OPENING HALF-CLOSED
6" OPENING CLOSED
PROBABLE
MAXIMUM
TRANSFORMER
SIZE
BASE LINE (POINT OF SPECIFIED TEMPERATURE
MEASUREMENT AND POSITION OF
TRANSFORMER BASE)
TEMPERATURE IN C°
0
10
20
30
40
50
60
70
80
90
100
110
120
130
0 2 4 6 8 10 12 14 16 18 20 22 TOP
DISTANCE ABOVE BASE IN INCHES
30 OCT. 1945
H. ROBERTSON

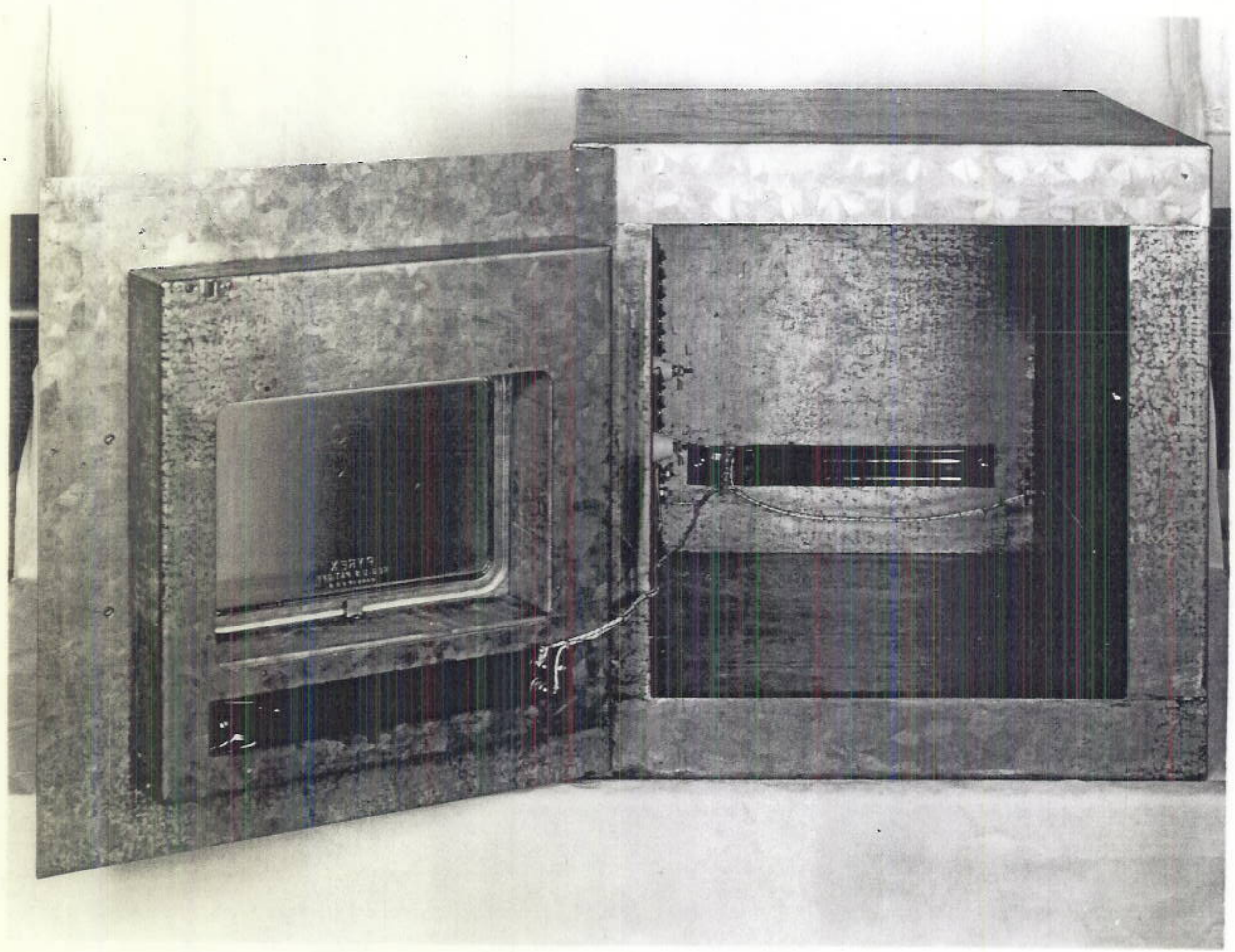


U. S. NAVAL RESEARCH LABORATORY WASHINGTON 20, D. C.		SCALE 1.5" = 1'-0"	PROPOSED TRANSFORMER TEST CHAMBER	
		DR'WN. G. L. ANDERSON		
B'LD'G. 68	PHONE 338	CH'K'D.		
ROOM 233	DATE 1-29-46	APPR'V'D H. S. ROBERTSON	UNLESS OTHERWISE SPECIFIED, TOLERANCES ARE ±	283

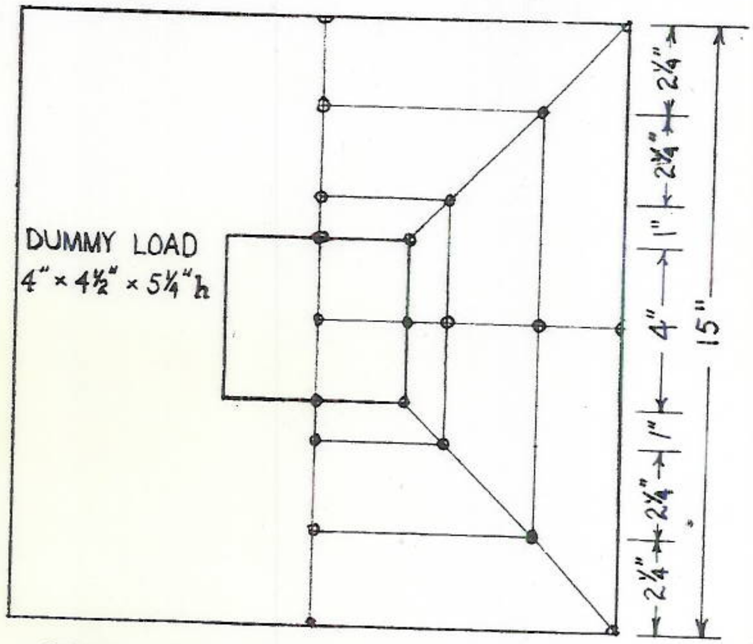
SHEET OF



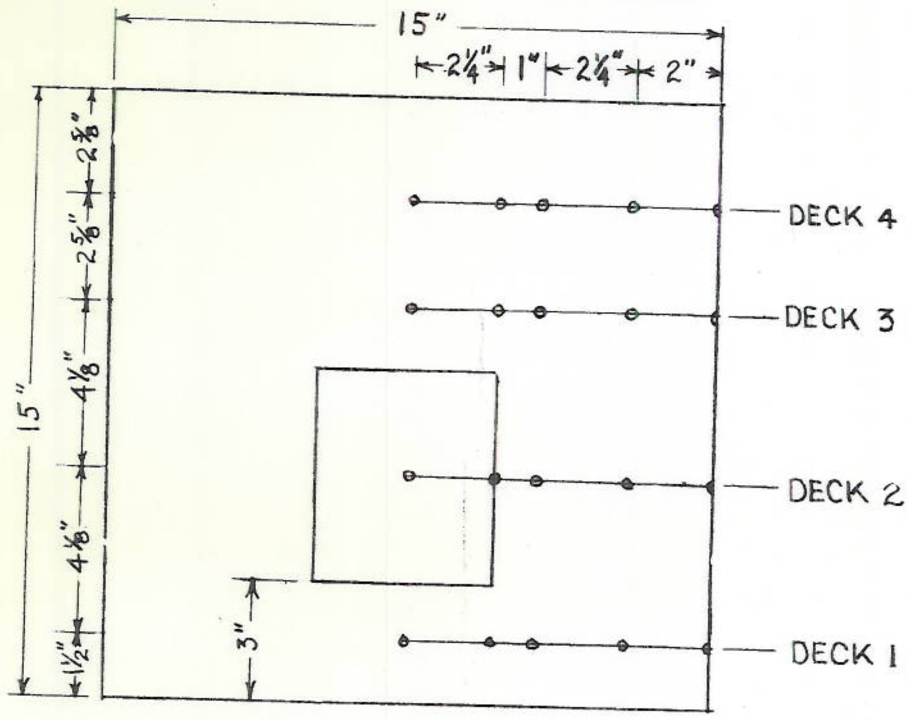
WORKING MODEL OF PROPOSED TRANSFORMER TEST CHAMBER



WORKING MODEL OF PROPOSED TRANSFORMER TEST CHAMBER
SHOWING LOCATION OF HEATERS.



DECK LAYOUT – PLAN VIEW



DECK LAYOUT – FRONT VIEW

EACH DOT REPRESENTS A THERMOCOUPLE LOCATION

R-2869

PLATE 5

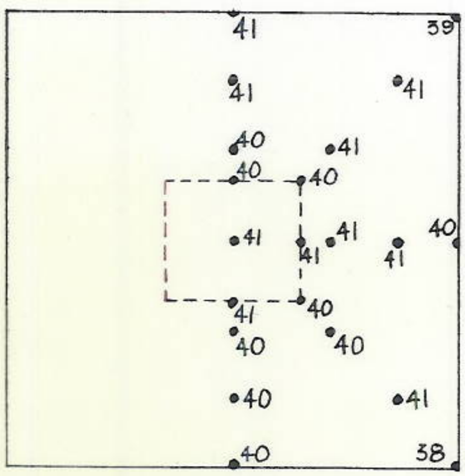
U. S. NAVAL RESEARCH LABORATORY
WASHINGTON 20, D. C.

B'LD'G. 68	SCALE ¼" = 1"	THERMOCOUPLE LOCATIONS IN TEST OF TRANSFORMER TEST CHAMBER	
	DR'WN. BWH		
PHONE 12	CH'K'D.		
ROOM 105	DATE	APPR'V'D.	

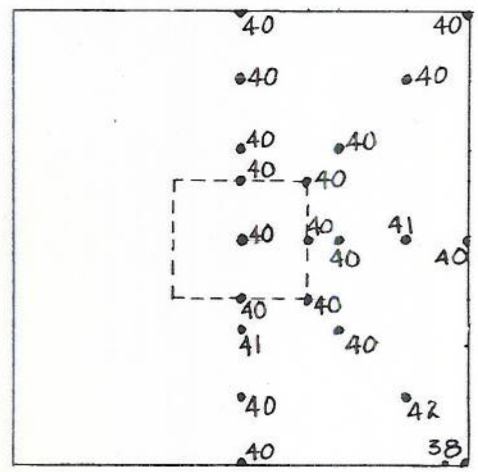
UNLESS OTHERWISE SPECIFIED, TOLERANCES ARE ±

SHEET OF

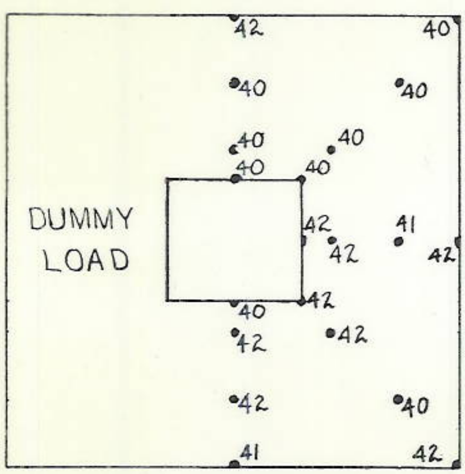
NAVSHIPS (NRL) 141



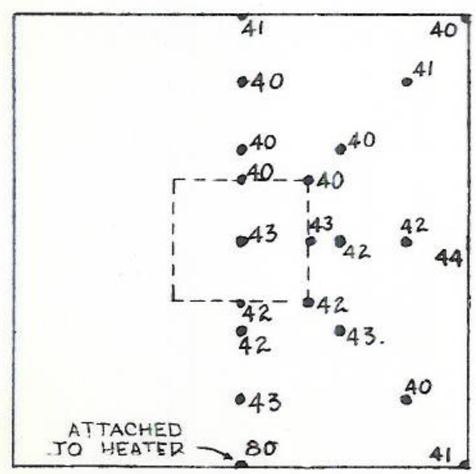
DECK 4 – 12⅜" FROM BOTTOM



DECK 3 – 9¾" FROM BOTTOM



DECK 2 – 5⅝" FROM BOTTOM



DECK 1 – 1½" FROM BOTTOM

40° CENT. CONTROLLED TEMPERATURE

NO INPUT TO LOAD

EACH DOT REPRESENTS A THERMOCOUPLE – ALL FIGURES ARE DEGREES CENTIGRADE

R-2869

PLATE 6

U. S. NAVAL RESEARCH LABORATORY
WASHINGTON 20, D. C.

B'LD'G. 68 | PHONE 12
ROOM 105 | DATE

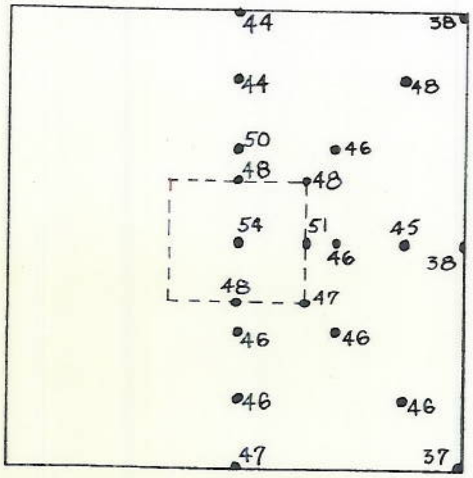
SCALE 3/16" = 1"
DR'WN. [signature]
CH'K'D.
APPR'V'D. [signature]

TEMPERATURE DISTRIBUTIONS IN TRANSFORMER TEST CHAMBER, – #1

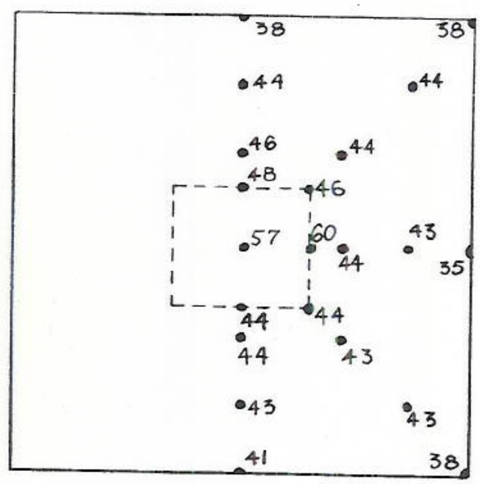
UNLESS OTHERWISE SPECIFIED, TOLERANCES ARE ±

SHEET OF

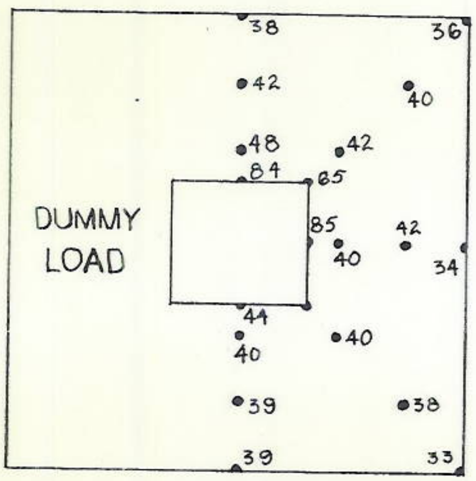
NAVSHIPS (NRL) 141



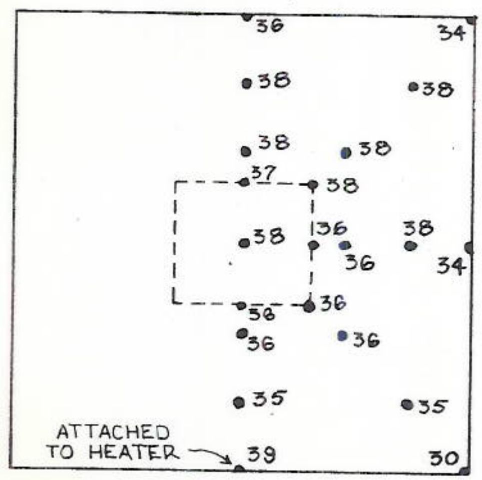
DECK 4 - 12⅜" FROM BOTTOM



DECK 3 – 9¾" FROM BOTTOM



DECK 2 – 5⅝" FROM BOTTOM



DECK 1 – 1½" FROM BOTTOM

40° CENT. CONTROLLED TEMPERATURE

50 WATTS INPUT TO LOAD

EACH DOT REPRESENTS A THERMOCOUPLE – ALL FIGURES ARE DEGREES CENTIGRADE

R-2869

PLATE 7

U. S. NAVAL RESEARCH LABORATORY
WASHINGTON 20, D. C.

B'LD'G. 68 | PHONE 12 | ROOM 105 | DATE

SCALE 3/16" = 1" | DR'WN. [signature] | CH'K'D. | APPR'V'D. [signature]

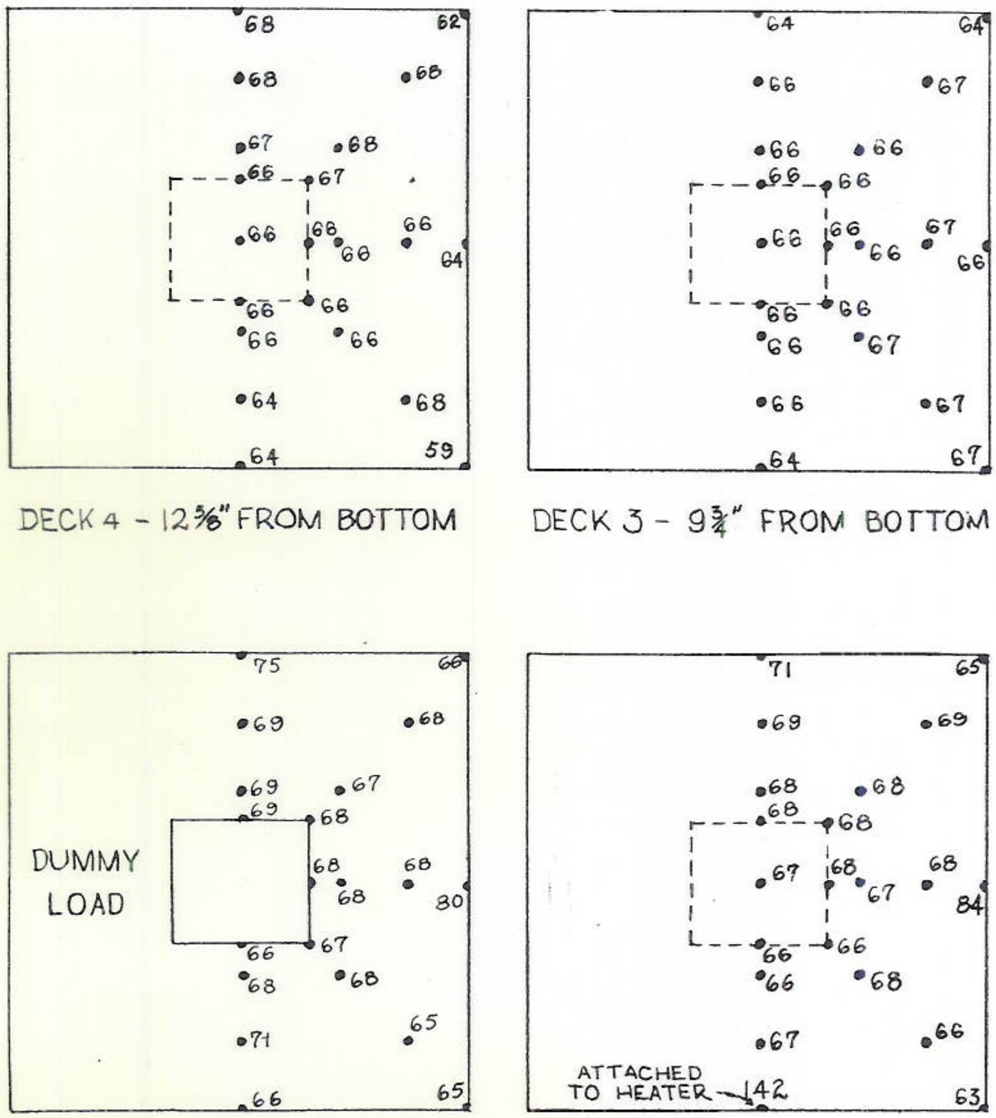
TEMPERATURE DISTRIBUTIONS IN TRANSFORMER TEST CHAMBER, – #2

UNLESS OTHERWISE SPECIFIED, TOLERANCES ARE ±

[redacted]

SHEET OF

NAVSHIPS (NRL) 141



DECK 4 - 12⅝" FROM BOTTOM

DECK 3 - 9¾" FROM BOTTOM

DECK 2 - 5⅝" FROM BOTTOM

DECK 1 - 1½" FROM BOTTOM

66° CENT. CONTROLLED TEMPERATURE

NO INPUT TO LOAD

EACH DOT REPRESENTS A THERMOCOUPLE - ALL FIGURES ARE DEGREES CENTIGRADE

R-2869

PLATE 8

TEMPERATURE DISTRIBUTIONS IN TRANSFORMER TEST CHAMBER - #3

UNLESS OTHERWISE SPECIFIED, TOLERANCES ARE ±

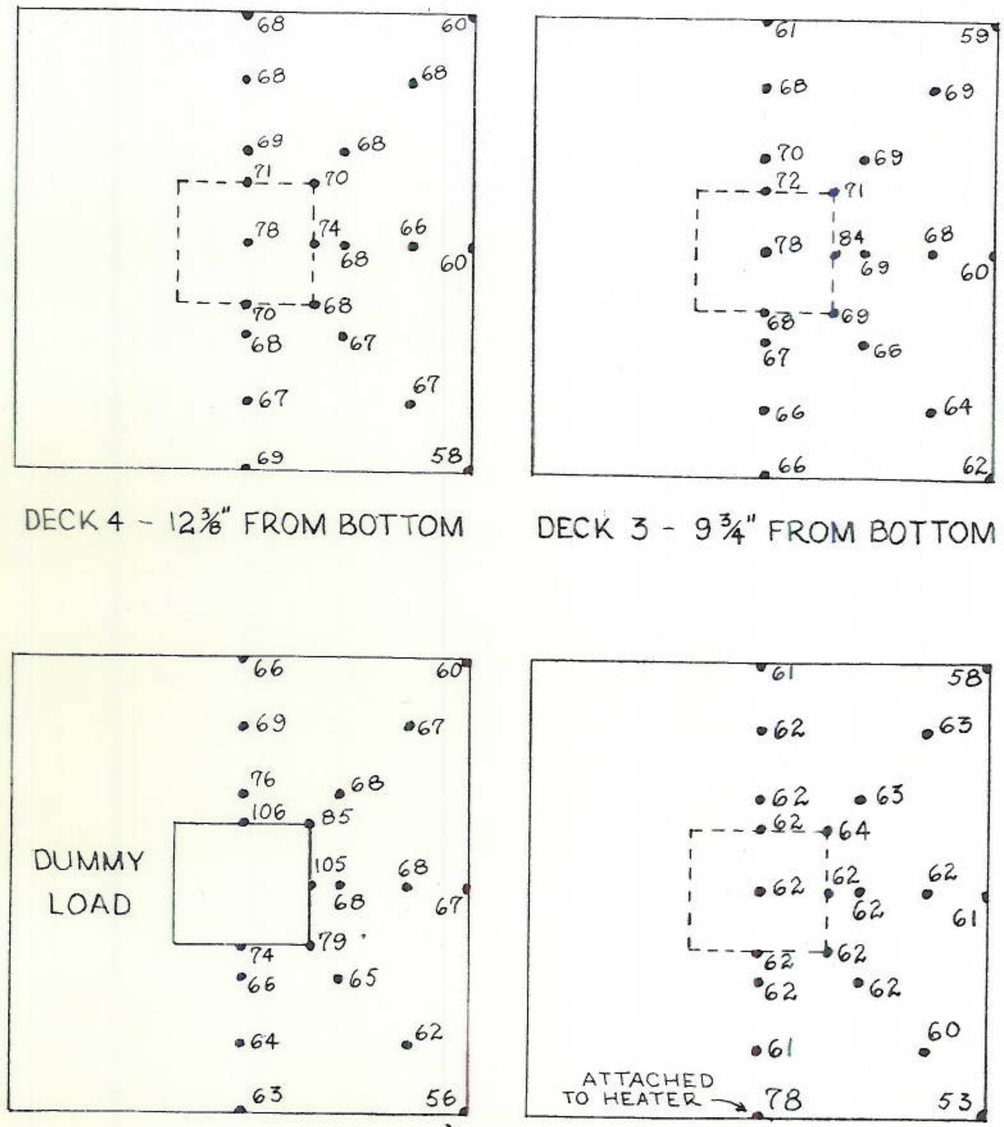
U. S. NAVAL RESEARCH LABORATORY
WASHINGTON 20, D. C.

SCALE 3/16" = 1"
DR'WN. BHH
CH'K'D.
APPR'V'D.

B'LD'G. 68 | PHONE 12
ROOM 105 | DATE

SHEET OF

NAVSHIPS (NRL) 141



DECK 4 - 12⅜" FROM BOTTOM

DECK 3 - 9¾" FROM BOTTOM

DECK 2 - 5⅝" FROM BOTTOM

DECK 1 - 1½" FROM BOTTOM

66° CENT. CONTROLLED TEMPERATURE

50 WATTS INPUT TO LOAD

EACH DOT REPRESENTS A THERMOCOUPLE - ALL FIGURES ARE DEGREES CENTIGRADE

R-2869

PLATE 9

U. S. NAVAL RESEARCH LABORATORY
WASHINGTON 20, D. C.

B'LD'G. 68 | PHONE 12
ROOM 105 | DATE

SCALE 3/16" = 1"
DR'WN.
CH'K'D.
APPR'V'D.

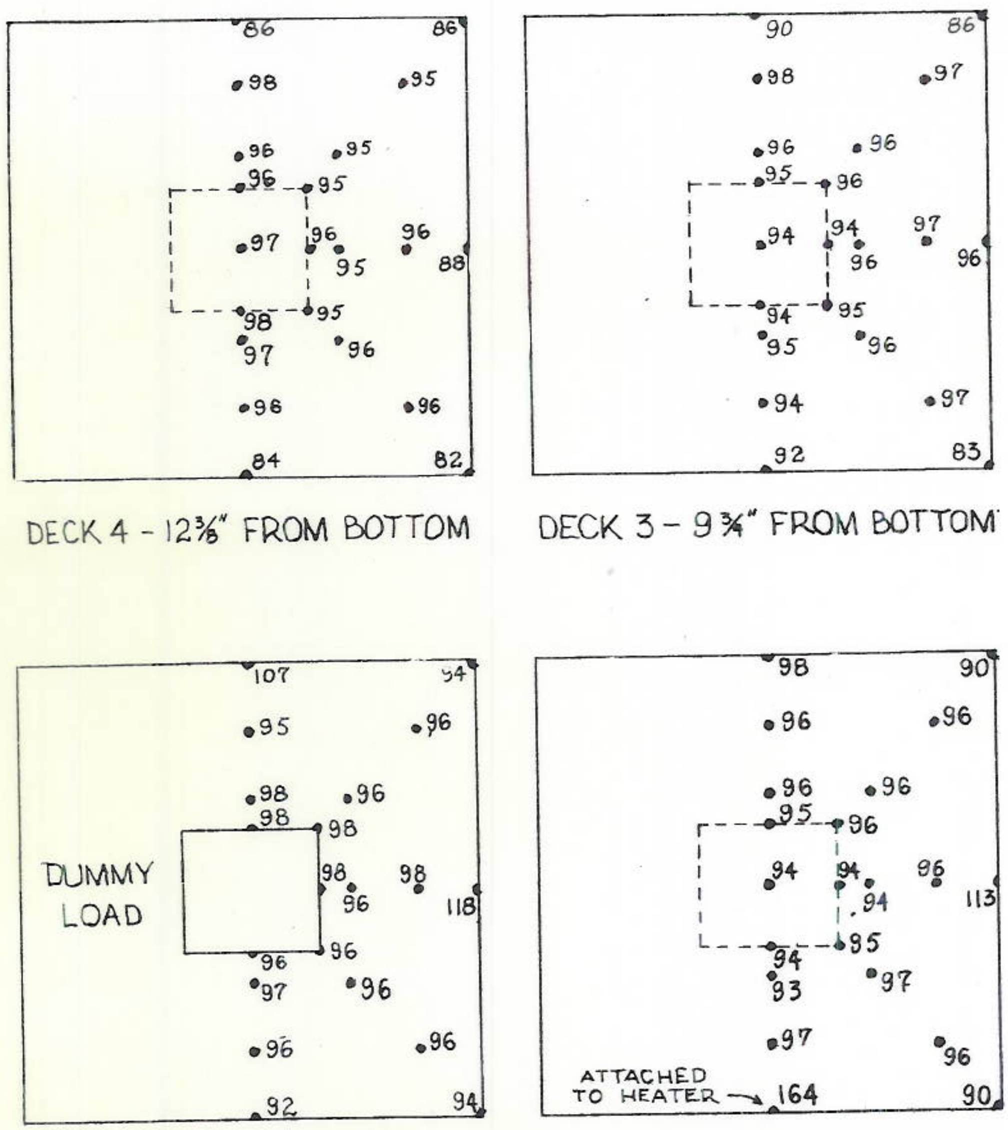
TEMPERATURE DISTRIBUTIONS IN TRANSFORMER TEST CHAMBER, - #4

[redacted]

UNLESS OTHERWISE SPECIFIED, TOLERANCES ARE ±

SHEET OF

NAVSHIPS (NRL) 141



DECK 4 - 12 3/8" FROM BOTTOM

DECK 3 - 9 3/4" FROM BOTTOM

DECK 2 - 5 5/8" FROM BOTTOM

DECK 1 - 1 1/2" FROM BOTTOM

98° CENT CONTROLLED TEMPERATURE

NO INPUT TO LOAD

EACH DOT REPRESENTS A THERMOCOUPLE - ALL FIGURES ARE DEGREES CENTIGRADE

R-2869

PLATE 10

TEMPERATURE DISTRIBUTIONS IN TRANSFORMER TEST CHAMBER - #5

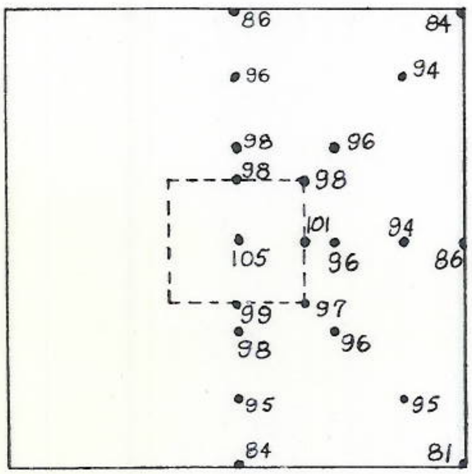
U. S. NAVAL RESEARCH LABORATORY
WASHINGTON 20, D. C.

SCALE 3/16" = 1"	
DR'WN.	BWH
CH'K'D.	
APPR'V'D.	
B'LD'G. 68	PHONE 12
ROOM 105	DATE

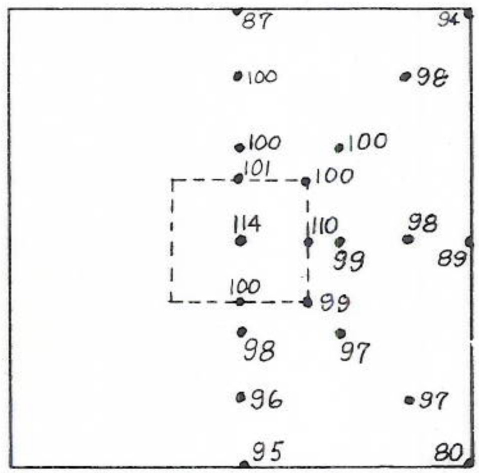
UNLESS OTHERWISE SPECIFIED, TOLERANCES ARE ±

SHEET OF

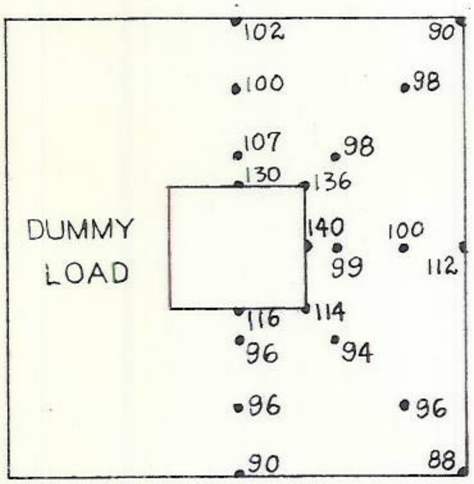
NAVSHIPS (NRL) 141



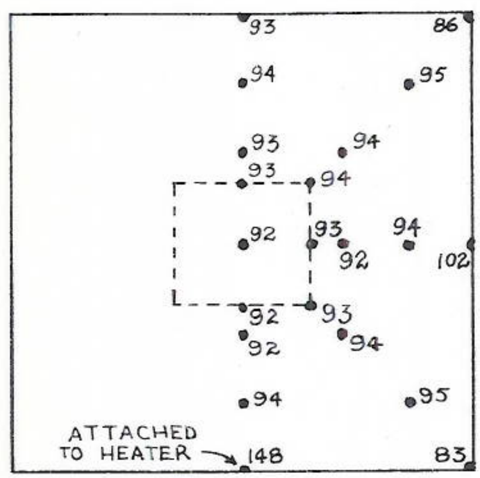
DECK 4 - 12⅜" FROM BOTTOM



DECK 3 - 9¾" FROM BOTTOM



DECK 2 - 5⅝" FROM BOTTOM



DECK 1 - 1½" FROM BOTTOM

98° CENT. CONTROLLED TEMPERATURE

50 WATTS INPUT TO LOAD

EACH DOT REPRESENTS A THERMOCOUPLE – ALL FIGURES ARE DEGREES CENTIGRADE

R-2869

PLATE 11

TEMPERATURE DISTRIBUTIONS IN TRANSFORMER TEST CHAMBER - #6

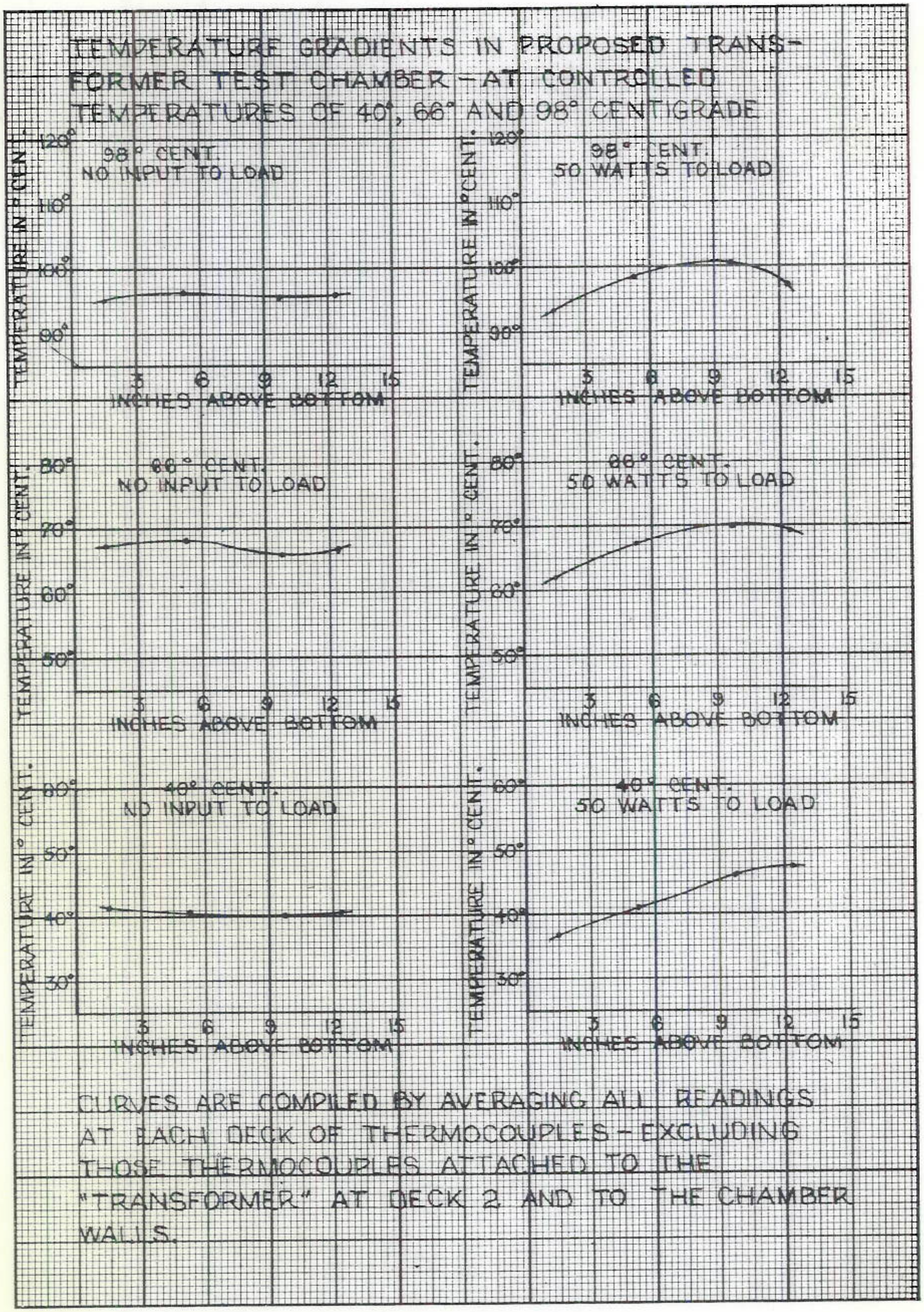
UNLESS OTHERWISE SPECIFIED, TOLERANCES ARE ±

SHEET OF

U. S. NAVAL RESEARCH LABORATORY
WASHINGTON 20, D. C.

B'LD'G. 68	PHONE 12	SCALE 3/16" = 1"	DR'WN. BHK
ROOM 105	DATE	CH'K'D.	APPR'V'D.

NAVSHIPS (NRL) 141


TEMPERATURE GRADIENTS IN PROPOSED TRANSFORMER TEST CHAMBER – AT CONTROLLED TEMPERATURES OF 40°, 66° AND 98° CENTIGRADE
98° CENT.
NO INPUT TO LOAD
98° CENT.
50 WATTS TO LOAD
66° CENT.
NO INPUT TO LOAD
66° CENT.
50 WATTS TO LOAD
40° CENT.
NO INPUT TO LOAD
40° CENT.
50 WATTS TO LOAD
TEMPERATURE IN ° CENT.
INCHES ABOVE BOTTOM
120°
110°
100°
90°
80°
70°
60°
50°
40°
30°
3
6
9
12
15
CURVES ARE COMPILED BY AVERAGING ALL READINGS AT EACH DECK OF THERMOCOUPLES – EXCLUDING THOSE THERMOCOUPLES ATTACHED TO THE "TRANSFORMER" AT DECK 2 AND TO THE CHAMBER WALLS.

Distribution:

BuShips - 6
ANEESA - 2
CHORI - 1
ORI, Boston - 1
SNLO, Ft. Monmouth - 5
OP-413-B2 - 5